Recommendations for a Department of Energy Nuclear Energy R&D Agenda

Appendix 3
Summary of Issues That Drive Nuclear Energy Research and Development

EXECUTIVE SUMMARY

Nuclear energy is a fundamental element of the United States' policies on national security, environmental quality, waste management, economic competitiveness, and institutional infrastructure; without this component, all would be weakened. For example, the policy of the United States to prevent proliferation of nuclear materials is not possible without the essential foundation of a nuclear energy program. At the same time, nuclear energy is a key component of the nation's energy security and diversity, providing nearly 22% of electrical generation in the country today. The environmental benefits of nuclear power are well known; and the use of nuclear energy has a smaller environmental impact than fossil fuel technologies, impacting the public well-being throughout the entire world. However, nuclear energy must maintain its competitive edge in the face of uncertainties such as utility deregulation, spent fuel disposal, and large decommissioning and decontamination costs.

Nonproliferation is a significant issue with nuclear power because the fissile materials used and generated in power production can be subverted for use in nuclear weapons. If the United States loses its leadership role in nuclear power generation, then the U.S. has a much more difficult task of exporting a culture of control of nuclear materials, which is essential to nonproliferation. Effective nonproliferation policies require the protection of enabling and supporting technologies. In addition, a nonproliferation approach could be built into exports to the world—if the United States has a position of world leadership. On the other hand, other countries that develop a commercial nuclear power industry will gain expertise in areas necessary for a nuclear weapons program. Any state or group investing the effort can acquire the experts and technology for nuclear technology; and this is why control of essential materials and technology is mandatory. With the decline of its nuclear industry, the United States is no longer the sole source of nuclear expertise or the major supplier of parts to the international nuclear market, and its attitude of nonproliferation consequently has less influence worldwide.

Internationally, nuclear plants in the former Soviet Union continue to operate in areas of economic uncertainty. Several of these plants are crucial to maintain a secure supply of electricity to the local region but suffer from the economics woes that often accompany a time of political change. The security of the energy supply is dependent on the continued safe and secure operation of these plants.

Nuclear energy is a key component to the stability of the energy infrastructure in the United States. A diverse fuel mix, including nuclear, is essential to the United States; it ensures that electrical power will be readily available at all times. Approximately 22% of the current U.S. electrical generation is provided by nuclear power. An infrastructure of nuclear technology is needed to preserve the reliability and stability in these 109 operating plants and to maintain the option of building advanced reactors.

As part of the essential energy supply of the United States, nuclear energy helps limit the production of carbon dioxide, nitrogen oxides, sulfur dioxide, and particulate emissions associated with fossil fuels. The environmental consequences, as the worldwide demand for energy burgeons, are a concern of increasing importance. Nuclear energy is an integral part of the energy mix in the United States at the moment, and must be for the foreseeable future if supplies of electricity are to remain adequate without an appreciable increase in the use of fossil fuels and an inevitable accompanying increase in carbon dioxide emissions. Because nuclear power plants do not use fossil fuels, they do not emit air pollutants.

Internationally, the demand for electricity is growing and is projected to nearly double between now and 2015. This is particularly true in Asia where the demand for electricity is growing at a phenomenal rate and there is a need to ensure that the global supply of energy is met without environmental degradation. The rapid growth in global demand for fossil fuel-driven new generation capacity, particularly coal-generated capacity in China and India, will be accompanied by proportional increases in air pollutant emissions. The environmental costs of these plants will affect the whole world, and alternative power generation technologies to these countries are necessary to prevent excessive environmental damage.

Safe, reliable, and cost-effective nuclear waste disposal is needed; this area presents a host of issues that are crucial to nuclear power in the United States. It includes not only high- and low-level waste disposal but also transportation of spent fuel and decontamination and decommissioning of nuclear facilities. Missing now is a national solution for waste disposition.

Nuclear power faces a number of challenges to survive in the impending era of utility deregulation. Thus, issues connected with economic competitiveness are high on the list of concerns. The amount of spent fuel generated by a utility directly contributes to the size of spent fuel storage pools and waste disposal costs. The economic competitiveness of the utility is greatly dependent on the minimization of spent fuel. Also, today’s consolidation and compaction methods will no longer be viable when large numbers of facilities must be decontaminated and decommissioned. While utilities have accumulated large decommissioning funds, these funds will not be adequate if utilities must use current decontamination and decommissioning (D&D) techniques.

The nation has more than a $200 billion investment in nuclear power plants and has the infrastructure for maintaining “American know-how” in nuclear technology. The major issues connected with the future of nuclear power must be resolved to ensure the future energy supply and environmental well-being of the country. The decline in the nuclear industry is resulting in an erosion of the technical knowledge base.

At present, funding is inadequate to maintain a meaningful nuclear program in the United States. Without continued research and development, the United States will no longer have the personnel to actively engage the international community and encourage a safety culture in other countries. If this trend continues, the Untied States, former leader in nuclear power, will be only an observer.

Finally, the successful application of nuclear energy in support of national security requires gaining public acceptance of the technology. While nuclear energy is accepted and being pursued enthusiastically in other countries, the U.S. public has not accepted it as anything more than an option for the future. The tide of negative information provided to the public must change to a new climate of open communication in order to obtain public trust and acceptance.

1.0 NATIONAL SECURITY ISSUES

The U.S. nuclear energy program is an important component of national security. U.S. policy to prevent the proliferation of nuclear materials is not possible without the essential foundation of a nuclear energy program. With an in-depth knowledge of the technologies of the nuclear fuel cycle and with a leadership position in the area of nuclear technology, the U.S. is positioned to provide credible leadership in the control and disposal of special nuclear materials and nuclear technology. U.S. involvement provides not only the basis for leadership but also for access to international relationships that allow us to directly monitor the nuclear activities of other countries. Without involvement, the U.S. does not have access to a dedicated professional community and must seek other means to gather this information.

1.1 Nonproliferation

An important issue with nuclear power is that the fissile materials used and generated in power production can also be used in nuclear weapons. The ability of a nation or group to develop a nuclear weapon is a function of the following:

- Material availability.
- Ability to obtain material from either spent fuel, reprocessing plant, or fuel fabrication facility.
- Enabling technology.
- Ability to separate and enrich the material into the needed type.
- Ability to produce the isotopes needed.
- Political "will" to develop weapons of mass destruction.
- Ability to proceed in isolation.

To work towards nonproliferation, the risks of all these must be reduced.

Materials Control

In protecting materials from subversion into weapons, both uranium and plutonium must be considered. Uranium is present in fresh fuel and spent fuel. Plutonium is present in spent fuel as well as that which has already been processed for weapon usage.

Large quantities of plutonium are accumulating as weapons are dismantled. Likewise, large quantities of plutonium are accumulating in the form of spent nuclear fuel. Technology is available for reprocessing spent fuel. While reprocessing technology is expensive, with the cost providing a proliferation barrier, restrictions on the export of this technology are essential to prevent diversion for weapons purposes. France extensively reprocesses its fuel, and Japan is currently developing a reprocessing program. The U.S. discontinued civilian reprocessing during the Carter administration to reduce the amount of plutonium that could be subverted for weapons use.

The primary issue surrounding materials controls supporting nonproliferation is to account for the material so that other nations have reasonable assurances that no materials are being subverted for weapon usage.

In addition, if the U.S. loses its leadership role in nuclear power generation, then the U.S. has a much more difficult, if not impossible, task of exporting a material control culture. Several regional and worldwide agencies have been developed such as EURATOM. These agencies provide materials controls for a region, ensuring each other a margin of transparency; however, such agencies do not cover all countries that have nuclear capabilities at this time, and they are subject to the cooperation of such governments.

Adding to the difficulty of encouraging material control is the change in the type of threat for subversion. Traditional materials control looked at the country-level of activity. Since the breakup of the Soviet Union, the possibility of subversion of materials by terrorist groups has become increasingly important.

A consideration in materials control is the diversion of hot cells and other supporting hardware and technology into weapons development.

Technology Dissemination

Nonproliferation also requires the protection of enabling and supporting technologies. By developing a commercial nuclear power industry, areas of expertise are developed. The U.S. has developed many nuclear engineering programs for the purpose of educating engineers and creating a technical infrastructure to support the nuclear power industry. The U.S. is still educating many of the world’s nuclear engineers. While commercial nuclear technology cannot be used directly to build a weapon, the technology can be the basis for beginning and sustaining a weapons development program.

The vitality of the commercial nuclear industry and the U.S. government philosophy of openness have resulted in an abundance of information in the open literature. If a potential proliferant state or group desires to invest in the effort, and has or can acquire the knowledgeable people and technology for nuclear technology, then it is difficult to stop them. Under Eisenhower’s Atoms for Peace Program, the IAEA was chartered to assist member states in developing nuclear industries. The idea was to have all such industries under safeguards, but the knowledge and experience gained thereby cannot be safeguarded. In addition, countries other than the U.S. have had rather low requirements for safeguards when exporting nuclear technology in the past, especially France. With the U.S. losing its leadership role in the nuclear industry, it is difficult to export a safeguards culture to prevent further dissemination of technology by other countries.

Other technologies are needed by proliferant states and groups, such as isotope production (with the theft of fresh fuel) and enrichment technologies, and much of this information is available in the open literature.

1.2 Physical Security of Nuclear Power Plants Worldwide

With the break up of the Soviet Union, several nuclear power plants have had a disruption in operations. New governments have formed within the new countries, and the responsibilities for oversight of the nuclear power plants have changed. These regions rely on the nuclear plants to supply large percentages of their electricity and residential heating, and the continued operation of these plants is essential to maintain the economic infrastructure. Many of these reactors are of the same type as Chernobyl and lack containment structures. The combination of the change in government and the lack of adequate safety systems makes these reactors particularly vulnerable to failures or accidents, leading to increased hardship in these regions.

When the U.S. began the Atoms for Peace Program, the IAEA was chartered with assisting member states with development of the nuclear industry including the safeguards and physical security of the nuclear plants. Countries other than the U.S. have a far more lax approach to the physical security of their nuclear power plants. With the U.S. nuclear industry declining and its share of the international market in jeopardy, the U.S. is in a poor position to export its own safeguards and security culture.

1.3 U.S. Leadership in Nuclear Energy Technology

The U.S. has always taken a strong stance in pursuing a nonproliferation policy of preventing commercial nuclear materials and technology diversion into weapons uses. However, with the U.S. nuclear industry on the decline and no longer the source of nuclear expertise or a supplier of parts to the international nuclear market, it can no longer have the same influence to encourage similar nonproliferating attitudes.

The U.S. needs to ensure that the option to use nuclear energy is available to meet the nation’s future energy needs. Internationally, competition for scarce fossil energy resources is likely to increase, and the demand for these fuels is reduced through nuclear energy. Numerous conflicts have been fought over energy resources and the ability to improve a nation’s standard of living using these resources. Current projections suggest that electrical energy consumption is growing at a rate of ~2%/year. Ideally, future demand growth will be met by a combination of renewable and nuclear energy, thus conserving fossil fuels for future generations and uses other than electrical energy generation. Nuclear energy has the potential to reduce international tension/conflict in that it can help meet the energy needs of developing nations. Major economic expansion in China, India, etc. will strain existing fossil fuel production capabilities and consume reserves at increasing rates.

1.4 Energy Security

Nuclear energy is a key component of the U.S. energy infrastructure, which would be weakened without this component. Approximately 22% of the current U.S. electrical generation is provided by nuclear power. An infrastructure of nuclear technology is needed to preserve the investment in these 109 operating plants and to support their continued operation in a safe, reliable, and environmentally friendly manner. Supporting R&D and technology transfer from government laboratories and universities is needed to reduce uncertainties in the license renewal option. This will maximize the economic benefit from the ~$200B investment in operating nuclear power plants. Internationally, the availability of nuclear energy technology provides options for other nations to improve their energy infrastructure, without aggression, and to obtain needed energy resources.

A diverse fuel mix, including nuclear fission, helps ensure that power is readily available to run the economy and ensure economic competitiveness. A tangible benefit of a diverse energy supply was clearly displayed on the East Coast during winter 1995. Coal piles were frozen, oil barges were stranded, and natural gas supplies were used primarily to heat homes and businesses. If they had been available, photovoltaics and wind power would have been incapacitated, too. Commercial nuclear power plants and power-wheeling prevented blackouts and reduced the number of brownouts. Whether the challenge is inclement weather or a political crisis (e.g., in the Persian Gulf), nuclear power is a secure domestic source of electrical energy.

2.0 ENVIRONMENTAL QUALITY ISSUES

2.1 CO_2 Emissions

Public well-being is supported by a U.S. program in nuclear energy because using nuclear energy instead of fossil fuels reduces CO_2 emissions. Promoting nuclear energy use, both domestically and internationally, will reduce CO_2 emissions without reducing power produced. Over 1.9 billion metric tons of carbon emissions have been avoided in the U.S. alone through the use of nuclear energy.

The ability to substantially curtail the production of CO_2 will strengthen the U.S. position in negotiations and demonstrates our commitment to the control of CO_2 emissions.

2.2 Air Pollution

Nuclear energy is more environmentally friendly than fossil fuel electrical generation. Electric power plants that burn fossil fuels emit air pollutants linked to the environmental problems of acid rain and urban ozone. These pollutants include volatile organic compounds (VOCs), nitrogen oxides (NOx); carbon monoxide (CO), particulate matter less than 10 microns in diameter (PM10), and sulfur dioxide (SO_2). At present, 72%, 35%, and 33% of the total U.S. emissions of SO_2, CO_2, and NOx, respectively, come from fossil fuel combustion at U.S. utilities.

A 1996 study by the Energy Information Administration (EIA) and the Federal Energy Regulatory Commission (FERC) examined the anticipated impacts of projected fuel prices, electricity demand, and proposed utility deregulation on the production of these air pollutants from electricity generation. In all of the scenarios evaluated in this study, air pollutant emissions were projected to steadily increase in the U.S. between 1996 and 2015, due primarily to increased fossil fuel consumption resulting from rising demand for cheaper electricity, the expected retirement of existing nuclear generation capacity, and the replacement of retired nuclear generation capacity by fossil fuel-based generation options. Moreover, world demand for electricity is projected to nearly double between now and 2015, with about half the increase coming from the developing world, which will rely on fossil fuels for over three-quarters of its electricity generation. This rapid growth in global demand for generation capacity, particularly coal-generated capacity in China and India, will be accompanied by proportional increases in air pollutant emissions.

Because nuclear power plants do not use fossil fuels, they do not emit air pollutants. By displacing the need to burn fossil fuels, nuclear energy has been a major contributor to reduced air pollution in the U.S. and the world. In the U.S., recognizing the problems caused by acid rain and urban smog, the Clean Air Act Amendments of 1990 mandated sharp emission reductions and placed annual limits on utility emissions of both SO_2 and NOx. In total, U.S. utilities must achieve annual reductions of 10 million tons of SO_2 and 2 million tons of NOx by the year 2000. In comparison, the nuclear industry notes that U.S. nuclear plants in 1994 already offset approximately 4.9 million tons of SO_2 and 2.3 million tons of NOx on an annual basis. And worldwide, in 1994, the 430 nuclear power plants in the world prevented the discharge to the atmosphere of 455 million tons of carbon, 15 million tons of sulfur dioxide, and 7 million tons of nitrogen oxide.

3.0 WASTE MANAGEMENT ISSUES

3.1 High-level Waste Disposal

Safe, reliable, and cost-effective nuclear waste disposal is needed. The scope of the effort must include spent fuel storage, transportation, and handling; high-level and low-level waste disposal; and decontamination and decommissioning of nuclear facilities.

Policy-based issues, including the decision to permanently dispose of spent fuel in geologic repositories, are perceived by the public as having negative health effects and environmental impacts. Having a national solution for high-level waste (HLW) disposition is currently missing. The issues facing waste disposal come from multiple, separate agencies. This issue can be addressed by establishing a uniform policy addressing radioactive, chemical, and mixed-waste issues.

High-level waste (HLW) disposal issues must be resolved soon. The government is developing a geologic repository and has obligated itself to take HLW from the nuclear industry. The plan for putting the waste into a geological repository represents a political and public acceptance challenge. However, the “political will” to implement the policy must be strengthened so we can proceed with the proposed disposal methods.

3.2 Depleted Uranium

The ongoing operation of the U.S. nuclear fuel cycle requires the operation of the U.S. uranium enrichment plants, which produce depleted uranium as a byproduct or waste material. Over 500,000 tonnes of depleted uranium exist as uranium hexafluoride, UF_6, and no decision or path forward exists on its disposition or disposal. This depleted uranium inventory has been stored for over 50 years against the scenario of its use as fertile material in fast breeder reactors. With the termination of the U.S. breeder reactor program the largest beneficial use for depleted uranium has disappeared, and questions exist concerning its disposal or beneficial use. Currently there are neither established commercial uses for depleted uranium nor is there any regulatory path forward for its disposal as waste (the NRC has indicated that it may not be disposed as low-level waste).

Although depleted uranium is not radiologically hazardous, the UF_6 form is chemically hazardous, and corrosion of UF_6 storage cylinders is a concern. Experience in the nuclear and chemical industries has been that the continued production of hazardous waste streams such as depleted uranium that have no disposal endpoint are eventually declared to be unacceptable by state authorities and public interest groups. As such, the lack of established beneficial uses or disposal pathways for depleted uranium represents a vulnerability for the U.S. nuclear energy option and thus requires attention.

3.3 Urbanization and Environmental Degradation in Developing Nations

As nations develop, their use of electricity will increase. This results in a need to quickly build power plants to meet the demand for electricity. Usually, a coal-burning plant is built without pollution controls or an accounting for the amount of carbon dioxide generated. The environmental costs of these plants will affect the whole world.

This is particularly true in Asia where the demand for electricity is growing at a phenomenal rate, and there is a need to ensure that the global supply of energy is met without degradation of the environment.

3.4 Safety Issues

It is the opinion of those knowledgeable about the nuclear industry, both from the regulating side and the industrial side, that U.S. nuclear plants are very safe. However, the low-probability, high-risk accident must be considered from both the prevention standpoint and the management standpoint.

Accident Prevention and Management

Accident prevention, in many ways, is the process of retrofitting existing plants and modifying new designs to incorporate lessons learned as the industry has matured. This process has continued throughout the history of the nuclear power plant industry and continues today. However, complete prevention requires a two-prong approach: not only must the design and the hardware of a plant be designed with safety as a driver, the operational personnel must also continually perform their jobs with safety as an integral part of the task at hand.

Reactor Safety Assurance Worldwide

Although we have reasonable assurances that the reactors in the U.S. are safe, the question remains as to how we assure ourselves that the rest of the world builds and operates plants as safely as possible. The IAEA and EURATOM were both established with this objective as part of their missions. The issue is that, while each of these organizations does inspect and monitor plants, neither of these organizations has the breadth to cover all nuclear plants.

Internationally, there needs to be a continued effort to retrofit plants in the former Soviet Union to make them safer and to instill a safety culture into the operations of these plants. With the demise of the USSR and the time it will take for the new countries to establish themselves, this effort is essential to maintain a secure supply of electricity to many of these regions.

4.0 ECONOMIC COMPETITIVENESS ISSUES

4.1 Decontamination and Decommissioning

Today’s consolidation and compaction methods will no longer be viable when large numbers of facilities must be decontaminated and decommissioned. While utilities have accumulated large decommissioning funds, these funds will not be adequate if utilities must use current decontamination and decommissioning (D&D) techniques. These costs may impact decisions regarding continued operation of the plant.

4.2 Impact of Utility Deregulation

Until today's "deregulatory" environment evolved for the electric utility industry, it was always assumed that a compact existed between regulators (such as state Public Utility Commissions) and regulated utilities. If a plant (such as a nuclear unit) were needed and the PUC allowed construction of such, then the utility was allowed to fully recover all of the costs, including capital amortization, associated with the facility as part of their rate structure. The agreement was made independent of the power generation mix and power prices in other utility's service areas or regions outside the plant's service area. When the electric power industry is deregulated, "captive" utility customers formerly committed to buy power from their regional utility will be allowed to shop for lower prices and drop their current utility. Such deregulation will introduce marketplace efficiencies into the electricity market; however, it will have the effect of leaving those utilities with higher-cost, unamortized generation investments, such as nuclear plants brought on line in the late 1970s through the early 1990s, with unrecovered capital costs. This part of the total power generation cost unrecoverable by revenues is called "stranded investment." Many nuclear utilities may face stranded investments in the billions of dollars if new legislation does not allow some form of recovery from former customers, such as "exit fees" from the utility system. Those nuclear plants with high production cost (O&M plus fuel) will also have a difficult time competing in a deregulated environment where large blocks of wholesale power will be sold for rates in the 1.5–2.5 ¢/kWh range. It is likely that older plants (those facing large investments such as new steam generators) and small plants (where costs are distributed over a smaller number of kilowatt-hours) will be the plants most likely to have production costs that are above the competitive range. These plants are very likely candidates for early shutdown, and a few such closures have already been announced in the past two years.

Historically, a regulated utility had a straightforward path for the raising of capital for new nuclear plant construction. Since the rate of return to investors was guaranteed by a compact with economic regulators (PUCs) and the revenues within a service region were guaranteed, the utilities normally had no difficulty borrowing money at reasonable rates (utility bonds) or issuing stock. The rates of return to investors were lower than for other industrial ventures, but the risk was also lower. In the new deregulated environment the above will no longer be true. The market will not be guaranteed; a nuclear plant will have to compete with other generation sources on the wholesale baseload market. The risk to both bondholders and stockholders will be significantly higher, hence higher rates of return on debt and equity will be required, perhaps by several points above typical utility returns. Small utilities are unlikely to be able to raise such financing, therefore consortia (such as independent power producers [IPPs] or teams of utilities, reactor vendors, fuel manufacturers, Architect/Engineers, etc.) may be required to finance and build such plants. Because of the licensing, siting, and public relations risk associated with nuclear projects, there may be additional premium on the return to investors.

The near term market for reactors, however, is not in the U.S. or Europe but rather in the developing world, mainly Asia. The problem in much of Asia, such as China, Indonesia, Thailand, and Vietnam, is the lack of indigenous capital needed for plant construction. It is likely that foreign investment on a massive scale will be needed to finance nuclear programs in these nations. There is also an institutional risk with such investments related to the stability of their governments and the lack of experience with capitalism and Western business practices. It is very likely that future nuclear plants will be financed in ways never foreseen when the last domestic reactor order was placed in the 1970s. The U.S. nuclear industry would greatly benefit from a study of how large, risky international projects, such as mining and petroleum projects, are financed. It is very likely that similar paths will be needed for the nuclear industry.

In addition to the cost effects of deregulation, there are other significant infrastructure and institutional issues, both positive and negative, that may arise. Four of these are:

- Economic pressure on utilities might force the utilities to cut costs in areas related to plant safety.
- Mergers and buyouts of utilities and plants will cause most nuclear plants to be owned and/or operated by very large, multi-regional utilities, each having several plants. Greater cost efficiencies may result from such an arrangement.
- Reactor equipment vendors and architect engineers may find themselves in the role of financing in addition to equipment manufacturing and construction for future nuclear plants built for the domestic U.S. market.
- Nuclear facilities may find themselves being used in a load-following or non-baseload mode. Since these plants were designed to provide baseload, operational efficiency may be impaired.

4.3 License Renewal and Plant Aging Management

Many nuclear plants will be reaching the end of their original operating license in the next 20 years. Renewing the operating license of safe, economically-competitive plants will allow a utility to recover its capital costs over a longer period, ultimately reducing the price of electricity and making the plant more economically competitive.

The regulatory process to renew an operating license for a period exceeding 40 years, as defined in 10CFR54 and known as license renewal, has not been demonstrated. To date, no utility has submitted a license renewal application. The first license renewal application will be submitted in late 1997 or early

1998. The NRC has suggested that it will take approximately three years to review the first application, obtain additional information, conduct hearings, and, if the application is judged acceptable, grant an amended license. The uncertainty associated with an unproven regulatory process can be reduced by accelerating efforts to resolve technical concerns (e.g., time-limited aging analyses such as fatigue) and the review and approval process.

Regardless of a utility's decision for plant license renewal, understanding the safety issues associated with plant aging will become critical in the next 20 years. Advanced techniques that can identify aging phenomena and mitigate problems will be needed. Stress corrosion cracking will become a significant issue. Plant infrastructure, like electrical cables, will need close examination to determine the impact of aging on safety.

4.4 Construction of New Plants

Capitalization

In the U.S., the competitiveness of existing nuclear power plants is very much determined by the extent to which the large capital costs have been amortized and by the electrical production cost (annual O&M costs plus fuel). Existing nuclear plants for which the capital costs have been amortized can produce electricity for 1.5–3.0 ¢/kilowatt-hour. Even in a deregulated market, these prices are competitive with the most economic of fossil fuels. New U.S. nuclear plants of evolutionary design are expected to have power generation (busbar) costs of 3.6–5.0 ¢/kilowatt-hour, which is not expected to be competitive with natural gas or coal-fired plants.

Constructibility

A long construction period leads to uncertainty in the total cost of construction, both as a function of time and materials escalation and changes in interest rate. Advanced construction techniques are required to minimize the construction period. While new Japanese and Korean nuclear power plants are built in less than five years, the U.S. has yet to demonstrate the ability to achieve similar results. There has been significant technology improvement in foreign infrastructure to construct nuclear power plants. A similar infrastructure has not been tested in the U.S. Two major DOE/industry efforts help reduce construction uncertainty. The Design for Constructability Program was completed in 1989, and the Construction Project of the Technology Program in Support of Advanced Light Waters was completed in 1991. While uncertainties have been reduced, closure is dependent on a program to build a new plant in the U.S. in less than five years.

The licensing process for new plants is defined in 10CFR52. Per the new process, a utility can obtain a construction permit and "provisional" operating license (i.e., all essential NRC approvals) prior to starting construction. The process depends on both an Early Site Permit (ESP) for a qualified site and construction of a “Certified Design.” The scope of public hearings that could delay plant startup are then limited to safety issues that have not been addressed during the design certification process; and the intervenor must demonstrate that a substantial safety concern has not been addressed in previous hearings. Two standard, evolutionary designs have been certified by the NRC: General Electric’s Advanced Boiling Water Reactor (ABWR) and ABB-Combustion Engineering's System 80+ pressurized water reactor (PWR). A third design certification review, of the Westinghouse AP600 advanced PWR design, is in progress. The first two phases of the ESP process have been demonstrated; the third phase will be completed when a utility proposes a candidate site. Hence, an issue remains that can only be overcome when a utility decides to build a new reactor. Ideally, improved economics of existing plants will motivate utilities to order new plants; however, incentives may be required to stimulate interest and begin construction before the necessary infrastructure withers away.

5.0 INFRASTRUCTURE AND INSTITUTIONAL ISSUES

5.1 Regulatory Framework and Certainty

Regulatory oversight is necessary; however, there is a consensus among both the NRC and the utilities that the current regulations need to be changed to reflect a risk-informed performance-based policy. Recent decisions by the NRC to abandon risk-informed policy in favor of defense in-depth (i.e., AP600 containment spray system) demonstrates the need for continued research. Regulatory changes and utility implementation are occurring slowly. This current atmosphere breeds an amount of uncertainty among participants.

Regulation of radiation exposure is inconsistent with data and is causing unnecessary public concern. Health physicists are beginning to realize that the linear, no-threshold model of radiation exposure is inaccurate and are beginning to move toward a baseline dose model. The consequences of a conservative model have caused unnecessary abortions in the wake of the Chernobyl accident by families who feared radiation damage based on the linear no-threshold model.

It is the opinion of most knowledgeable people that U.S. nuclear power plants are very safe. However, while there is a need to be inside the circle of safety, there is an increasing belief that that circle is too small and that the utilities are spending far too many resources in excessive safety measures.

Also in the regulatory framework is the issue of interagency cooperation. The EPA and the NRC are currently debating the residual limit of radioactivity in a cleaned-up site, with the EPA holding to a lower limit (15 mrems/year ground and 5 mrems/yr for water) than the NRC (25 mrems/year, all sources). Regardless of the merits of the debate, without clear lines between which agency has jurisdiction over certain areas of regulation and subsequent enforcement, the utilities may find themselves unable to accommodate both sides at the same time.

5.2 Availability of Qualified Vendors

The nuclear industry is in a state of decline in the U.S. with no new plants having been started since the late 1970s. Until recently, the U.S. had dominated the nuclear power industry and exported all of the hardware used in the western world's nuclear reactors. As other countries have picked up manufacturing expertise and are advancing the design of their reactors, the U.S. no longer provides hardware or parts to the international market. Consequently, the vendors that had produced nuclear power plant hardware in the past have significantly dropped their capacity for manufacturing parts to maintain the currently operating plants.

5.3 Nuclear Energy Needs of U.S. Government Agencies

Nuclear technology developments should not be made in isolation. Particularly in the face of a shrinking industry, there is a need to share research, insights and lessons learned between the commercial nuclear industry and other areas that the government is working on such as stockpile stewardship, naval propulsion, and risk-assessment technology. There is a need to provide interesting research opportunities to attract intelligent people to the field to maintain the core of technology in the commercial industry.

5.4 Resources for R&D Infrastructures

Currently, funding resources are inadequate to maintain a meaningful U.S. nuclear program. Increased funding is essential to restoring the U.S. as a world leader in the nuclear power industry. Without the ability to attract intelligent people to the field through providing research funds, the industry will lack a sufficient pool of personnel to provide an infrastructure for the nuclear industry.

Without the R&D activities, the U.S. is at a disadvantage for participating in international conferences and will have a decreasing opportunity to encourage a safety culture with other countries. The U.S. will no longer have the personnel to actively engage with the international community on an exchange basis. It will only be as an observer, decreasing credibility of the U.S. to encourage a safety culture in foreign reactor operations.

6.0 OTHER CONSIDERATIONS

6.1 Public Acceptance Issues

The successful application of nuclear energy in support of national security requires gaining public acceptance of the technology. Although nuclear energy is accepted and being pursued enthusiastically in other countries, the U.S. public has not accepted nuclear power; they are only interested in preserving the option to use nuclear energy in the future. Public acceptance will likely never be gained without a serious crisis to force a change in public perception (e.g., the U.S. had no interest in small, high-mileage vehicles until the Arab Oil Embargo).

In general, the support for nuclear power is highest in communities closest to nuclear power plants, while support declines rapidly with distance from the facilities. Recent de-facto changes in nuclear policy, however, involving the construction of semipermanent dry storage facilities for spent nuclear fuel on site at generating facilities have begun to erode community support.

Attitude surveys show a declining proportion of the public in favor of more nuclear power plants (less than 30%) and only a tiny fraction willing to have nuclear or hazardous waste facilities within 100 miles. The decline in public acceptance over the past 20 years is broadly spread among all stakeholder groups except the pro-nuclear support core of about 15–20%. There is an anti-nuclear opponent core of similar size (about 20%), but the remaining 60% is a vast undeclared, uncommitted, and nonattentive middle group. Besides community support, the only other bright spot is a growing proportion of the general public (more than 40%) that grudgingly admit that nuclear power may have an important role to play in the U.S. energy future.

A recent *Nuclear News* article claims that journalists are aware that nuclear energy is the safest form of power production yet also know that articles in favor of nuclear power will not sell newspapers, magazines, or air time.[1] The tide of negative information provided to the public must change; a new climate of open communication is needed to obtain public trust and acceptance.

The declining support for nuclear power has several components that must be understood and acknowledged before steps can be taken in an attempt to reverse this slide. Some of these components include:

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[1]"Turning the Tide of Public Opinion on Nuclear Power," *Nuclear News,* April 1997, pp. 26–30.

- Past history and record of secretive, arrogant, closed decision-making about nuclear matters and pollution at Cold War defense sites.
- Nuclear fears and radiation phobia based on the dread and fear conjured up by mushroom-cloud images and white-suited workers in gas masks.
- The nuclear enterprise has mostly chosen a passive-reactive approach to public acceptance, with little effort to counter antinuclear rhetoric or inaccurate information about radioactivity, etc.
- The size of the pronuclear constituency has declined. With the demise of many U.S. nuclear vendors and support infrastructure, this group is largely silent in the face of antinuclear rhetoric.
- Nuclear opponent groups mostly define and frame nuclear energy issues in the absence of a proactive stance by either the government or the nuclear industry.
- Little effort is expended on defining or interacting with the various sets of stakeholders at the local, state, and national levels.

Despite scientific studies showing that atomic bomb survivors and radiation workers experience minimal long-term health effects, the fantasy effects portrayed in certain entertainment products continue to dominate public perception. Traditional technical and logical arguments comparing nuclear power to radon in basements or medical/dental diagnostic x rays are ineffective because the public perceives risk differently depending on who is "in control." People feel safe in their homes and trust their health care providers; they don't trust the government and power companies. Just as most people feel safer in their own car than flying because the FAA, air traffic control, and pilots are responsible for air travel, power plants controlled by utilities and the NRC are not perceived to be safe (and statistical evidence will never convince them otherwise). Public acceptance of nuclear power must be linked to energy security, reduction of CO_2 emissions, and the need to provide world leadership. Without public acceptance of nuclear energy, revitalization of the industry will not happen because the industry will be too reluctant to invest the capital needed to build new plants.

The U.S. situation is in direct contrast to the situation in France. In general, the French have embraced nuclear energy. In fact, multiple towns/regions vie against one another to be selected for the next plant construction project. This attitude extends beyond plant construction and operation to the entire fuel cycle. The French government initially proposed a geologic repository, which was unacceptable to its population. Public debate and further study altered the proposed approach to a storage facility that is monitored by an independent agency responsible for verifying that the waste remains in a safe form andthat the people and environment are protected.

A recent PBS Frontline special, “Nuclear Reaction,” that aired on April 20, 1997,[2] is an excellent source of information containing both anti- and pro-nuclear views of commercial nuclear power.

The following list summarizes issues in public acceptance of nuclear technology implementation. Further work and analysis is required to develop options, tailored strategies, and possible solutions.

- Local public acceptance for relicensing existing nuclear power plants is not assured.
- Local public acceptance of continued storage of spent nuclear fuel (dry or wet) at some of the 70 nuclear power plant sites appears to be problematic.
- The Low Level Radioactive Waste Policy Act of 1980 may need further revision to define acceptable levels of radiation.
- The socio-political gap between the technical and nontechnical worlds continues to widen, making productive dialog increasing difficult.
- Local and national public acceptance of new nuclear power or nuclear waste management facilities must be developed.

[2]A videotape of the show is available from WGBH, Boston. Another alternative for obtaining additional information is on the Web at [http://www.pbs.org/wgbh/pages/frontline/shows/reaction].